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United States
Department
of Agriculture

Forest Service

Intermountain
Research Station

Research Paper
INT-412

October 1989

Effects of Prescribed Fire on Biomass and Plant Succession in Western Aspen

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THE AUTHORS

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NORBERT V. DeBYLE (retired), when this work was accomplished, was an ecologist in the Intermountain Research Station's Aspen Ecology and Management research unit in Logan, UT. He now is an associate professor in the Forest Resources Department, Utah State University, Logan. He received a B.S. degree in 1953 and an M.S. degree in 1957 from the University of Wisconsin and a Ph.D. degree in forestry in 1962 from the University of Michigan. While employed with the Intermountain Station from 1961 to 1987, he did research on water yield improvement, fire effects on water and soils, and aspen ecology and management.

RESEARCH SUMMARY

Plant succession and production of biomass were determined for three prescribed fires in aspen (*Populus tremuloides*) and aspen-conifer forests. Forbs and shrubs dominated the understories. Preburn fuel loadings ranged from 19,200 to 56,400 kg/ha. Fires ranged from low to high severity and overstory mortality from 20 to 100 percent. Total fuel consumption alone was poorly related to fire severity. Over 4 postburn years, production of grasses and forbs averaged 1.5 to 3.3 times that of the controls. Maximum production was 2,240 kg/ha, five times that of the associated control. High-severity fire favored forbs over grasses. After 5 years, shrub biomass was 21 to 100 percent of preburn biomass. The proportion of shrub biomass less than 0.5 cm diameter peaked after 2 years. Species responses were varied. Aspen sucker densities peaked during the first 2 postburn years and ranged from one-half to fivefold their preburn densities. Suckering was most prolific following fire of moderate to high severity. The varied patterns of seral vegetation and their management implications are discussed.

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INTRODUCTION

The widespread quaking aspen (*Populus tremuloides* Michx.) forests in western North America are lightly used for wood products. But they are valued highly as wildlife habitat, for grazing by domestic livestock, as sources of water, and for esthetics and recreation (DeByle 1985). Aspen exists as both a seral and climax species, but it is seral on a majority of sites (Mueggler 1976). Replacement of seral aspen by conifers in the West is gradual and may take 200 to 400 or more years (Bartos and others 1983). This successional process reduces forage production, water yield, and diversity of wildlife habitat (DeByle 1985).

In the past, fire played a prominent role in the perpetuation of aspen forests. Today, however, the existence of seral aspen is threatened by lack of fire in areas of the West (DeByle and others 1987). Prescribed fire offers an economical and environmentally acceptable means of rejuvenating aspen. It can be used successfully if fuel situations and weather conditions are favorable (Brown and Simmerman 1986) and if enough of the overstory is killed (Brown and DeByle 1987). To use prescribed fire effectively, forest managers must know how aspen and understory vegetation will respond to fire of known characteristics. Production of understory vegetation and successional patterns following fire have received only limited study in the western aspen types (Bartos and Mueggler 1981).

This paper reports the results of research undertaken to determine biomass response of seral vegetation and its relationship to fire severity in aspen and mixed aspen-conifer forests.

METHODS

A 120-ha prescribed fire was conducted at Manning Basin northeast of Montpelier, ID, in the Caribou National Forest. Two 1-ha fires were conducted on the Little Bear and Blue Jay drainages north of Kemmerer, WY, in the Bridger-Teton National Forest. Study sites were selected prior to burning to provide a range of surface fuel loadings in aspen and mixed aspen-conifer stands (table 1). Mixed stands were defined as conifers occupying at least 35 percent of the canopy.

At Little Bear and Blue Jay, three square macroplots (30 m on a side) were placed in each stand. Two macroplots were burned, and one remained as the control. At Manning Basin two aspen stands and one mixed stand were burned. Pairs of macroplots were placed in the mixed stand and in the upper elevation aspen stand (U). A single macroplot was placed in the lower elevation aspen stand (L). Single control macroplots for mixed and aspen stands were installed after the fire near the burn perimeter.

Inside the macroplots, 16 subplot centers were permanently located in a uniform grid, with 4 m between the outer subplot centers and the macroplot edge. Subplots varied in size and shape to allow adequate and efficient sampling of downed dead fuels, herbaceous vegetation, shrubs, and small trees. Biomass, cover, and density of understory fuels and vegetation were estimated on the fixed subplots prior to burning. Understory vegetation and ground cover were sampled each year afterwards. Measurements were always taken during the first 2 weeks of August, after peak annual growth of biomass. In addition to the measurements, we made a species list for each macroplot during the annual sampling by a cursory "walk around." Each species was assigned to one of seven cover categories, from only a few plants to more than 75 percent area cover.

Downed woody fuel loadings were determined for 0 to 0.6 cm, 0.6 to 2.5 cm, 2.5 to 7.6 cm, and greater than 7.6 cm diameter classes using the planar intersect method (Brown 1974). Sampling planes were randomly oriented at each subplot. Weights of grasses and forbs were estimated separately on 30- by 60-cm subplots using the weight-estimate method (Hughes 1959; Francis and others 1979). To calibrate ocular estimates of biomass, eight subplots were also systematically located about 2 m outside the macroplot. On these, grass and forb weights were estimated, then clipped, ovendried, and weighed. Forest floor material was sampled on a 30- by 30-cm portion of these subplots also using the weight-estimate method. The forest floor consisted of litter (01 horizon) and some duff (02 horizon), material that would probably undergo flaming combustion and consisting of freshly cast leaves, needles, and other detached plant parts as well as partially decayed material in the upper fermentation layer.

Shrubs, except for myrtle pachistima (*Pachistima myrsinites* [Pursh] Raf.), were sampled by tallying stems by basal diameter classes on 4-m^2 subplots. Biomass was computed using weight versus stem diameter relationships (Brown 1976). To check accuracy of these relationships for first-year sprouts, 30 sprouts for five shrub species were collected and weighed. Comparison of predicted and weighed sprouts showed good agreement for three species and acceptable agreement for the other two. The existing relationships were expected to apply with little

Table 1—Vegetation, fuel, and topographic conditions by stands

Condition	Stand identification				
	Little Bear	Blue Jay	Manning	Manning	Manning
Overstory	Aspen	Mixed	Mixed	Aspen(U)	Aspen(L)
Mean age of dominants (yr)	73	81	102	92	92
Treated plot basal area (m²/ha)[1]					
Aspen	16	26	8	17	14
Conifer	0.5	13	13	0	0
Treated plot average d.b.h. (cm)					
Aspen	16	16	15	12	15
Conifer	—	18	18	—	—
Community type[2]	POTR/RUOC	POTR-ABLA/ BERE	POTR-PSME/ CARU	POTR/PRVI	POTR/PRVI
Understory fuel[3]	Tall forb	Forb	Forb	Shrub	Shrub
Downed woody fuel	Heavy	Light	Medium	Medium	Heavy
Elevation (m)	2,440	2,440	2,225	2,380	2,225
Aspect	East	East	East	East	East
Slope (percent)	15	15	20	30	20

[1] To convert from m²/ha to ft²/acre multiply by 26.6.

[2] Community types conform to classification by Youngblood and Mueggler (1981) and Mueggler and Campbell (1982). Abbreviations are *Populus tremuloides* (POTR), *Abies lasiocarpa* (ABLA), *Pseudotsuga menziesii* (PSME), *Rudbeckia occidentalis* (RUOC), *Berberis repens* (BERE), *Prunus virginiana* (PRVI), and *Calamagrostic rubescens* (CARU).

[3] The classification of understory fuel types was based on amount of shrubs and productivity of herbaceous vegetation (Brown and Simmerman 1986).

error. Weight of myrtle pachistima was determined using estimates of cover and height in a weight algorithm developed by Olson and Martin (1981). In addition to stem counts, seedlings of snowbrush ceanothus (*Ceanothus velutinus* Dougl. ex Hook.) were counted and a subsample weighed. Aspen suckers were tallied in three classes on these 4-m² subplots (0 to 0.5 m and 0.5 to 2 m height and 2 m height to 5 cm diameter at breast height [d.b.h.]). Sucker biomass was computed from the stem counts and weight per stem relationships (Bartos and others 1983). All weights were expressed on an ovendry basis. Cover of shrubs, mineral soil, and litter was ocularly estimated on the 4-m² subplots. Cover of grasses and forbs was ocularly estimated on the 30- by 60-cm subplots. Conifers less than 3 m tall were tallied on the 4-m² subplots. All trees greater than 5 cm d.b.h. were tallied by 5-cm d.b.h. classes over the entire macroplot.

The fire at Blue Jay was ignited thoroughly throughout the plots on August 20, 1981, using a handheld drip torch. Air temperature was 24 °C, and relative humidity was 25 percent. Although fuel moisture content was low (5 to 7 percent fine fuel), the fire failed to spread beyond most points of ignition due to compact litter, sparse fine fuels, and low windspeeds. Some clumps of fuel burned and caused torching of a few subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.) and lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) Duff smoldered for several days in a few small areas, exposing a limited amount of mineral soil.

The fire at Manning Basin was ignited on September 22, 1981, in a line fire pattern using a helicopter drip torch. Moisture content was 8 percent in litter and in 0.6- to 2.5-cm diameter woody material, and 9 percent in woody material greater than 7.6 cm in diameter. Herbaceous vegetation was 40 to 50 percent cured. Temperature was 18 °C and relative humidity was 20 percent. Windspeed varied from 6 to 13 km/h. Fire spread at high intensity into the upper elevation aspen plots but failed to burn in the corner of one plot. At the lower elevation, the flames spread by backing, flanking, and making small headfire runs (fig. 1). Flaming persisted for several minutes due to burnout of large fuels in the lower aspen stand.

The fire at Little Bear was ignited on September 23, 1981, in a line fire pattern using a handheld drip torch. Moisture content was 7 percent for litter and 5 percent for 0.6- to 2.5-cm diameter dead woody material. Herbaceous vegetation was about 50 percent cured. Temperature was 17 °C and relative humidity was 20 percent. Windspeed was mostly 0 to 6 km/h, with gusts to 6 km/h. The fire spread slowly, going out in places at the lower windspeeds, but it spread with a sustained front during the brief wind gusts.

Fuel consumption and fire severity were determined by revisiting the subplots inside macroplots within a few days after burning. Downed woody material was reinventoried along the same transects. Herbaceous vegetation, shrubs, small trees, and litter consumption were ocularly estimated as a fraction of the preburn material that was consumed on each plot. Postburn measurements were taken for 5 years except for herbaceous material, which was heavily grazed in the fifth summer before sampling was possible. Fire severity on each macroplot was rated according to one of the following categories:

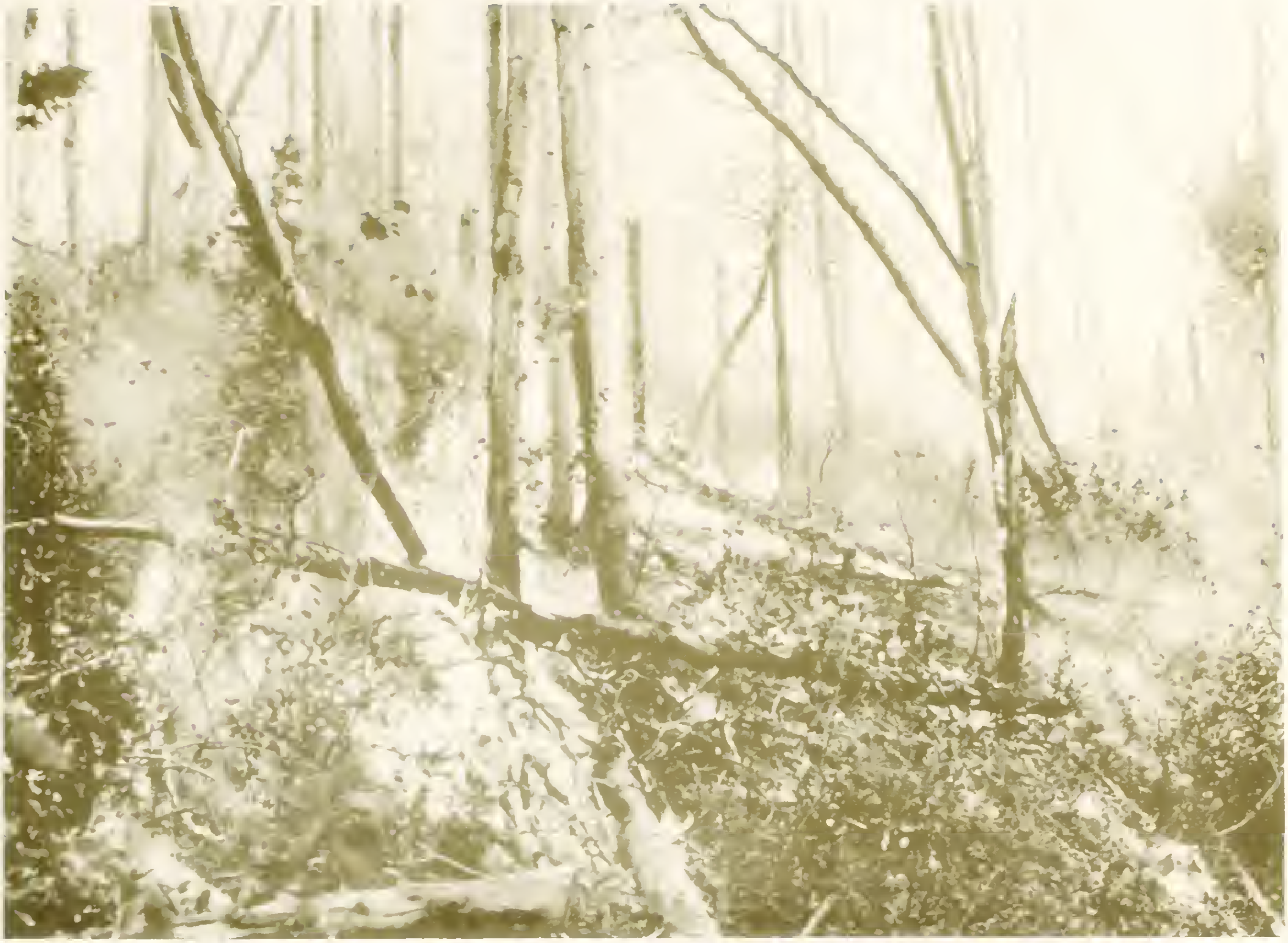

Figure 1—Flanking fire at Manning Basin produced flames from 0.5 to 1.5 m in length and effectively killed overstory aspen.

Low—Litter charred but not entirely consumed; shrubs partially killed; less than half of aspen stems killed.

Moderate—Litter consumed, duff deeply charred, but with some remaining charcoal; shrubs killed and partially consumed; most aspen stems charred and appeared killed.

High—Litter and duff completely consumed and mineral soil exposed; shrubs mostly consumed; all aspen stems killed.

Fire severity is a qualitative measure of the total effects of fire on the ecosystem. It reflects mortality to flora and fauna and loss of organic material, which involves the effects of upward and downward heat flux. Upward heat flux, expressed by fireline intensity or flame length, is largely responsible for aboveground plant mortality. Downward heat flux relates to fuel consumption and exposure of mineral soil. It was rated based on a ground char classification by Ryan and Noste (1985). Fuel consumption (table 2), flame length, exposed mineral soil, area burned, and tree mortality (table 3) were measured to help quantify fire severity.

Changes in annual production of herbaceous vegetation due to weather and site variability complicate interpretation of fire effects. To reduce these complications, the data were normalized to productivities of the control plots as a common base. At Little Bear and Blue Jay, site differences between macroplots were adjusted by (1) dividing preburn biomass on burned macroplots by that on control plots, and then (2) dividing all burned macroplot estimates, for all years, by this ratio. Yearly weather differences were adjusted by (1) dividing control postburn biomass for each year by control preburn biomass, and then (2) dividing all burned macroplot estimates for a given year by the ratio for that year. Tables 4 and 5 contain the observed annual production and normalization factors. The postburn adjustment ratios for burned treatments in table 5 are the product of site and weather ratios. The values for control treatments are weather adjustment ratios. As an example of adjustment for site differences, the ratio for grasses at Little Bear was 0.333 (table 5) obtained by dividing 226 by 679 in table 4.

Table 2—Preburn fuel loadings and percentage of preburn fuel consumed by fire

Location	Overstory-understory	Downed woody fuel (cm)				Forest floor	Grass forbs	Shrub	Fines[1]	Total fuel
		0-0.6	0.6-2.5	2.5-7.6	7.6+					
					Preburn loadings (kg/ha)					
Little Bear	Aspen-forb	[2]150	1,050	7,170	45,710	1,380	900	31	2,130	56,390
Blue Jay	Mixed-forb	590	2,250	3,650	4,260	8,260	46	130	3,020	19,190
Manning	Mixed-forb	530	2,410	5,360	17,590	8,550	330	1,640	4,910	36,410
Manning (U)	Aspen-shrub	450	2,140	5,470	2,760	8,940	490	880	3,960	21,130
Manning (L)	Aspen-shrub	700	3,630	9,360	27,380	10,570	350	1,800	6,480	53,790
					Consumed (percent)					
Little Bear	Aspen-forb	39	14	37	47	67	69	90	40	46
Blue Jay	Mixed-forb	76	75	79	100	18	26	27	72	56
Manning	Mixed-forb	77	67	27	33	66	57	21	52	43
Manning (U)	Aspen-shrub	67	48	32	55	64	82	33	51	52
Manning (L)	Aspen-shrub	93	57	60	93	73	89	68	65	80

[1] Includes 0-2.5-cm downed woody fuel, grass, forbs, and shrubs.

[2] Standard errors of the estimate for preburn fuel loadings on individual macroplots averaged 22 percent of the means for 0-2.5-cm downed woody fuels, 36 percent for large woody fuels, 13 percent for forest floor, 28 percent for herbs, and 20 percent for shrubs.

Table 3—Predominant flame length of propagating fire front, net mineral soil exposed by fire, percentage of macroplot burned, percentage of aspen and conifer trees killed, and fire severity class

Location	Overstory-understory	Plot No.	Predominant flame length	Mineral soil	Area burned	Year 1 mortality	Severity
			- - - - *m* - - - -	- - - - - - - - - -	*Percent*	- - - - - - - - -	
Little Bear	Aspen-forb	4	0.1-0.3	10	37	19	Low
	Aspen-forb	5	0.1-0.3	12	40	3	Low
Blue Jay	Mixed-forb	10	0-0.1	1	19	20	Low
	Mixed-forb	11	0-0.1	1	18	18	Low
Manning	Mixed-forb	50	0.2-1.0	34	60	20	Moderate
	Mixed-shrub	51	0.2-1.0	21	57	53	Moderate
Manning (U)	Aspen-shrub	52	1-5	44	78	85	High
	Aspen-shrub	53	1-5	22	72	41	Moderate
Manning (L)	Aspen-shrub	54	0.5-1.5	33	91	99	High

Table 4—Observed production of grasses and forbs

Location	Stand	Treatment	Year from fire P	1	2	3	4
					kg/ha		
			Grasses				
Little Bear	Aspen	Burned	226	708	907	284	376
	Aspen	Control	679	1,128	555	400	424
Blue Jay	Mixed	Burned	3.9	55	18	39	73
	Mixed	Control	66	123	93	88	108
Manning	Aspen(U)	Burned	314	542	504	554	716
	Aspen(L)	Burned	313	891	652	453	383
	Aspen	Control	[1]657	778	543	559	745
	Mixed	Burned	337	303	430	444	545
	Mixed	Control	[1]350	448	225	354	373
			Forbs				
Little Bear	Aspen	Burned	829	1,108	762	862	722
	Aspen	Control	482	772	1,188	1,140	1,095
Blue Jay	Mixed	Burned	41	251	124	183	82
	Mixed	Control	176	489	334	376	239
Manning	Aspen(U)	Burned	157	1,118	2,239	1,265	890
	Aspen(L)	Burned	34	338	572	870	436
	Aspen	Control	[1]462	449	397	445	558
	Mixed	Burned	29	329	587	561	462
	Mixed	Control	[1]313	291	337	344	280

[1] Average production from the 4 postburn years.

Table 5—Normalization factors to adjust observed biomass for differences in site and yearly weather

Location	Stand	Treatment	Year from fire P	1	2	3	4
			Grasses				
Little Bear	Aspen	Burned	0.333	0.554	0.272	0.196	0.208
	Aspen	Control	1.00	1.662	.817	.589	.624
Blue Jay	Mixed	Burned	.0593	.1105	.0834	.0794	.0965
	Mixed	Control	1.00	1.864	1.407	1.339	1.627
Manning	Aspen(U)	Burned	.478	.566	.396	.407	.542
	Aspen(L)	Burned	.476	.546	.394	.406	.540
	Aspen	Control	1.00	1.184	.828	.852	1.135
	Mixed	Burned	.965	1.237	.622	.978	1.030
	Mixed	Control	1.00	1.282	.644	1.013	1.067
			Forbs				
Little Bear	Aspen	Burned	1.720	2.755	4.240	4.068	3.908
	Aspen	Control	1.00	1.602	2.465	2.365	2.272
Blue Jay	Mixed	Burned	.236	.655	.448	.505	.320
	Mixed	Control	1.00	2.777	1.898	2.140	1.357
Manning	Aspen(U)	Burned	[1]1.00	.973	.859	.964	1.209
	Aspen(L)	Burned	[1]1.00	.973	.859	.964	1.209
	Aspen	Control	1.00	.973	.859	.964	1.209
	Mixed	Burned	[1]1.00	.929	1.075	1.096	.893
	Mixed	Control	1.00	.929	1.075	1.096	.893

[1] Adjustments for site differences between control and treatment plots were not made due to inadequate estimates of preburn biomass.

At Manning Basin, two problems added difficulty to interpreting the data. We were unable to install control plots prior to burning, and preburn sampling was done in September when an unknown quantity of forbs had cured and disintegrated, particularly in the lower elevation stands. However, grass biomass was still intact. Thus, forb production was adjusted only for yearly weather, but grass production was adjusted for both site and weather. To adjust for site differences, production on control macroplots was assumed to be the average production on those macroplots over the 4 postburn years. This seemed appropriate because production and growing season precipitation were unrelated in the postburn data. Thus, the average postburn production should be a reasonable estimate of the preburn production.

RESULTS

Preburn fuel loadings ranged from 19,200 to 56,400 kg/ha (table 2). (Pounds per acre are 89 percent of kilograms per hectare, so these units are similar for many considerations.) Data were combined for paired macroplots because preburn loadings and consumed fuel quantities were similar. The large difference in loadings among stands was primarily due to downed woody material greater than 7.6 cm in diameter (large fuel). Downed woody fuel loadings less than 7.6 cm diameter (small fuel) for the mixed/forb and aspen/shrub stands were similar to fuel loadings found in a variety of conifer types in the Northern Rocky Mountains (Brown and See 1981). But loading of downed woody fuel less than 2.5 cm diameter was very low in the Little Bear aspen/forb stand.

The sampled forest floor fuel quantities were primarily from the upper 2 cm of forest floor and consisted of litter and some duff (table 2). In separate measurements, the total duff layer averaged 36,500 kg/ha in the mixed controls at Blue Jay and 47,300 kg/ha at Manning. In the aspen control plots, total duff averaged 7,780 kg/ha at Manning and was nearly nonexistent at Little Bear. In a related study, quantities of litter averaged only about 1,900 kg/ha and were similar for aspen and mixed stands (Brown and Simmerman 1986). Except for the Manning mixed/forb stand, which contained high shrub loadings, the herbaceous and shrub fuel loadings were low compared to a classification of similar fuel types (Brown and Simmerman 1986). Based on this same classification, probability of successfully applying prescribed fire was moderate in the stands with forb understories and high in the shrub understories.

Fire Severity and Mortality

At Little Bear, the fire spread primarily in grass and forbs supported by newly fallen leaves (400 kg/ha). Fire severity rated low, even though approximately 21,500 kg/ha of large woody fuels were consumed. In spite of a heavy preburn fuel loading, 53 percent of the large fuels remained unburned because insufficient woody fuel less than 2.5 cm diameter was available to ignite the large woody pieces, which averaged 16 cm in diameter. The burnout time of grass was too short to ignite much of the woody material. The lack of woody fuels less than 2.5 cm diameter hinders flammability where aspen overstories and forb understories dominate because aspen crowns produce little fine-sized branchwood. At Blue Jay, even though fire severity was low, most of the woody fuels were consumed because they were concentrated in a few patches of subalpine fir. All patches of fuel were hand ignited.

At Manning Basin, fire severity rated moderate to high mainly because the fire spread well, consuming large quantities of forest floor and killing much of the aboveground vegetation. Shrubs were a significant component of fine fuel consumption that largely determines fireline intensity and flame length. Rapid ignition using jelled gasoline dropped by helicopter accounted for the large flames in the upper aspen stand. Considering all treatments, large fuel and total fuel consumption were not a good indicator of fire severity. Area burned and consumption of forest floor and fine fuels related most closely to fire severity (tables 2 and 3).

After 3 years at Little Bear, 21 percent of the aspen had died on the treated plots. Mortality continued, and after 5 years it was approximately twice the mortality on the control macroplot (table 6), which averaged 3.5 percent annually. Although the fire at Little Bear killed aspen, the effect on apical dominance was probably small because considerable live aspen remained to produce auxin.

The first year after fire at Blue Jay, a much greater proportion of conifers had died than aspen. But after 3 years, 40 percent of the aspen had died, exceeding the mortality rate of conifers. After 5 years, an even greater percentage of aspen and conifers had died, with small changes on the controls (table 6).

At Manning, 85 percent or more of the aspen had died after 3 years on the treated macroplots, and after 5 years nearly all of the aspen had died. All aspen were dead 1 year after fire in only one stand. In the mixed stand, about 30 percent of the conifers were killed but mortality was not apparent until the second year after fire. A major shift in the overstory occurred in the mixed stand where density of conifers, predominantly Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), increased from 48 to 93 percent of the total tree density (table 6).

Small conifers (<5 cm d.b.h.) were reduced from 5,000 to 2,000 per hectare, with mortality occurring over a 4-year postburn period in the mixed stand at Blue Jay. Similarly, two-thirds of the few small conifers in the mixed stand at Manning were killed. Small conifers were absent in the other stands.

Table 6—Change in stand density of live aspen and conifers greater than 5 cm d.b.h. from preburn to 1 and 5 year postburn periods based on a 100 percent inventory

Location	Stand	Treatment	Year from fire			Change from preburn to	
			Preburn	1 yr	5 yr	1 yr	5 yr
			Trees per hectare			*Percent*	
			Aspen				
Little Bear	Aspen	Burned	739	677	445	–8	–40
	Aspen	Control	655	—	536	—	–18
Blue Jay	Mixed	Burned	1,184	996	652	–14	–45
	Mixed	Control	1,184	1,161	978	2	–17
Manning	Mixed	Burned	413	138	15	–66	–96
	Mixed	Control	—	712	506	—	[1]–29
	Aspen(U)	Burned	1,497	544	79	–64	–95
	Aspen(L)	Burned	326	0	0	–100	–100
	Aspen	Control	—	1,107	699	—	[1]–42
			Conifers				
Blue Jay	Mixed	Burned	376	245	240	–35	–36
	Mixed	Control	319	363	363	+14	+14
Manning	Mixed	Burned	326	306	193	–6	–41
	Mixed	Control	—	835	647	—	[1]–22

[1] Change from postburn year 1 to year 5.

Grasses and Forbs

Fire stimulated grass and forb production in both aspen and mixed overstory types (fig. 2). In the treated stands, production of herbaceous vegetation over the 4-year postburn period averaged 1.5 to 3.3 times more than the control plots. Production during postburn year 1 ranged from 0.9 to 3.6 times that of the controls. Overall, burning doubled production over the 4 postburn years. The greatest increase in production occurred during the second postburn year. Averaged over 4 years, the percentage of herbaceous biomass comprising forbs increased substantially following fire at Manning Basin (from 8 to 52 percent for the mixed stand and 22 to 59 percent for the aspen stands). But the percentage of grass was increased at Little Bear (21 to 40 percent) and at Blue Jay (9 to 22 percent).

Grass production was substantially greater in the aspen than in the mixed stands (fig. 2). Maximum production in aspen was 4.5 times that in the mixed stands. Nevertheless, the greatest increase relative to controls occurred in the mixed stand at Blue Jay, where preburn production was meager. Although fire severity was low at Blue Jay, increased light from a reduced canopy may have aided a strong response. Coverage of grass increased slightly from preburn to postburn year 4 in all treated stands. Robust growth and extensive flowering of pinegrass (*Calamagrostis rubescens* Buckl.) accounted for the strong early postburn response of grass in the lower Manning aspen.

Average production of forbs during all postfire years was three times greater in the aspen stands than in the mixed stands. Forb production generally increased but not with any consistent pattern. The largest responses were in years 2 and 3 at Manning. Because forb production at Manning could not be adjusted for site differences between controls and treated plots, the relative change in production due to fire was probably underestimated. Average coverage of forbs increased from 12 percent in the preburn year to 30 percent in postburn year 4 for the aspen stands and from 4 to 20 percent for the mixed stands.

The relative decrease in postfire forb production in the Little Bear aspen stand (fig. 2) appeared to be caused by a large increase in pocket gopher activity compared to the control. Dense pocket gopher populations can reduce forb production (Teipner and others 1983). Maximum forb production was more than five times that of the control in postburn year 2 at the Manning upper aspen stand. Most of the production was from wild hollyhock (*Iliamna rivularis* [Dougl.] Greene), a species absent in preburn vegetation (fig. 3). It grew tall (2 m) and dense and dominated the site for several seasons. Biomass of wild hollyhock was sampled near the upper aspen stand where it was dense and lush. It averaged 2,260 kg/ha during postburn year 2 and 940 kg/ha in year 3. By year 4, biomass of wild hollyhock had declined further and its foliage appeared considerably more chlorotic. By postburn year 6, it had almost disappeared. It displayed great capacity to reestablish from dormant seed in the soil following fire.

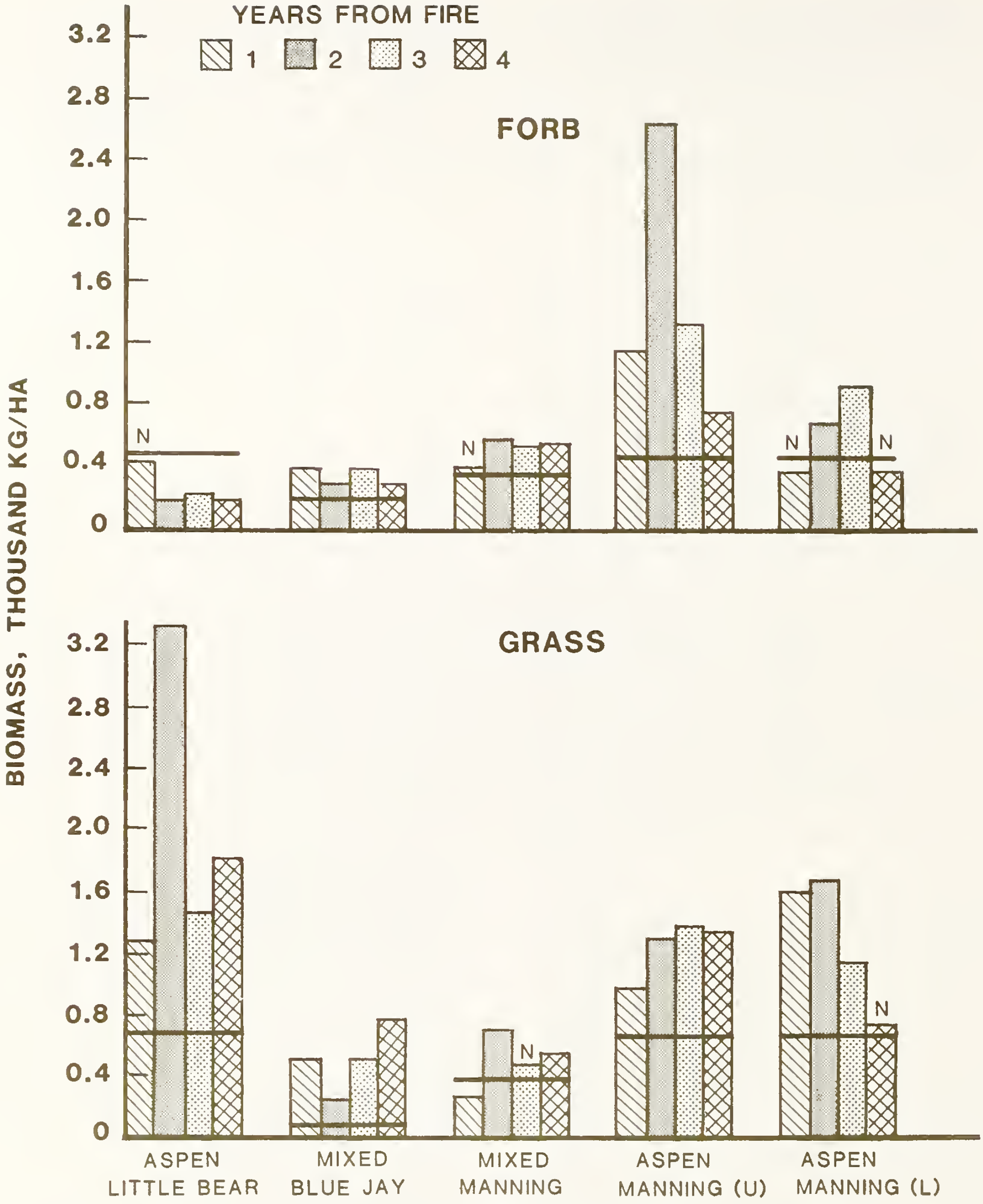

Figure 2—Adjusted biomass production of forbs and grasses following fire. Production of controls is shown by a horizontal line. Standard errors of estimates expressed as a percentage of mean production averaged 18 percent for grasses and 14 percent for forbs. An N placed above a bar means that the control and treatment were not significantly different based on a paired comparison t-test at the 90 percent confidence level. Otherwise, treatments and controls differed significantly.

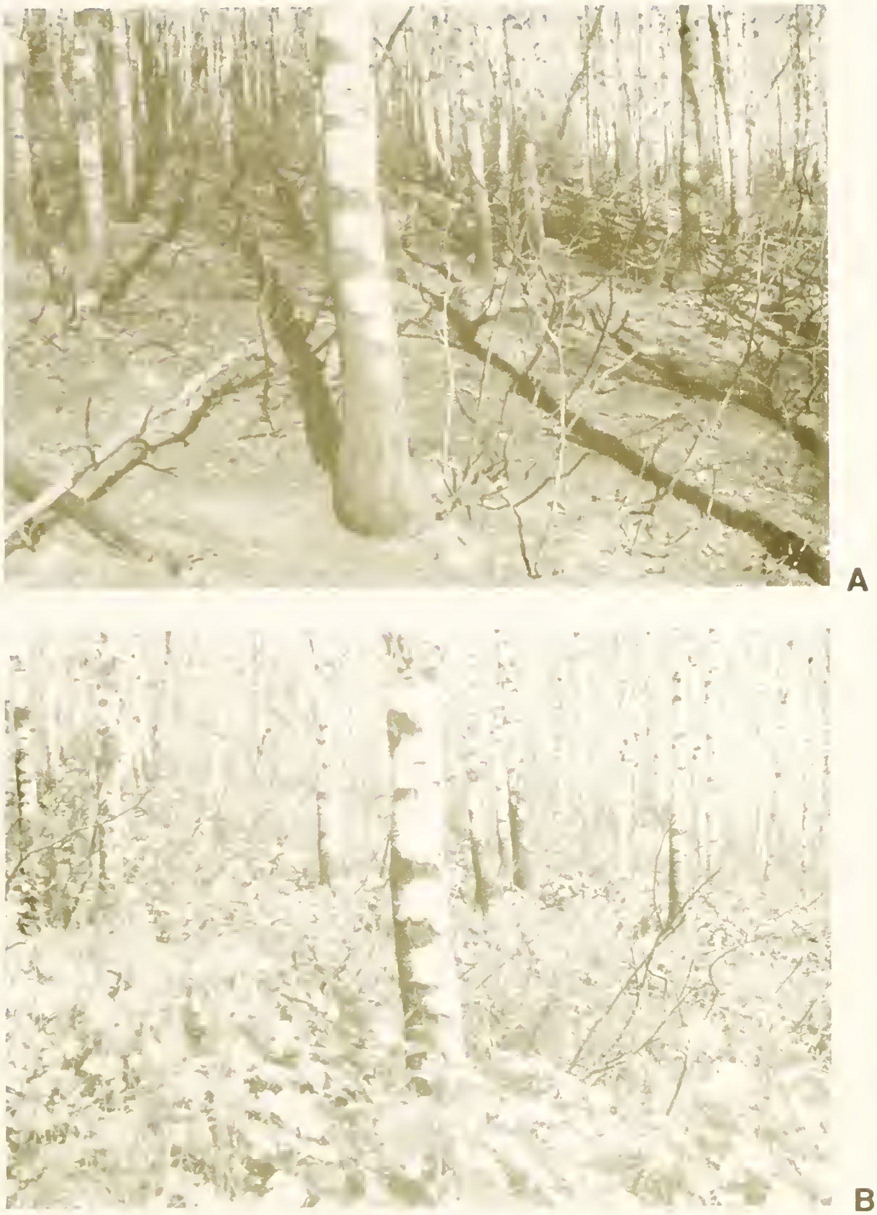

Figure 3—One week (A) and 1 year (B) after fire at Upper Manning Basin. Wild hollyhock (*Iliamna rivularis*) dominates the postburn vegetation.

By sampling density of seed pods and seeds per pod, number of seeds produced in year 2 was estimated at 14,300 per square meter. In a study of mature forest seedbanks in central Idaho (Kramer and Johnson 1987), density of wild hollyhock was 1,470 per square meter, the largest stored seed density in a single stand among 80 species.

The response of forbs to fire at Manning was similar to that found by Bartos and Mueggler (1981) in a Wyoming aspen stand with a forb-dominated understory. There, common fireweed (*Epilobium angustifolium* L.) increased dramatically in some areas, similar to the response of wild hollyhock on our sites. They found that grass production decreased the first year following fire, then increased; whereas we observed grass production to increase the first year. After a high-intensity prescribed fire in a central Idaho Douglas-fir stand, Lyon (1971) reported that wild hollyhock and common fireweed dominated vegetal cover until postburn year 6. Besides the striking appearance of wild hollyhock, false dragonhead (*Dracocephalum parviflorum* Nutt.) appeared as an important species in the aspen-conifer mix after fire. It appeared as a rosette in 1982, flowered in 1983 (year 2), and then faded away through years 1984 through 1986. Likewise, woodland strawberry (*Fragaria vesca* L.) occupied more than 5 percent cover in the burned mixed plots; it endures fire (Rowe 1983) and may be competitive in the postfire community. Common fireweed and duncecap larkspur (*Delphinium occidentale* Wats.) were not evident before burning but after burning became important species in the aspen plots, perhaps as invaders. Table 7 lists important species by cover class.

Table 7—Understory vascular plant species that provided more than 5 percentage cover on at least one macroplot by coverage classes

Species	Aspen-conifer mixed forest				Pure aspen forest			
	Untreated	Year 2	Year 4	Location[1]	Untreated	Year 2	Year 4	Location[1]
Grasses and Sedges								
Agropyron caninum	[2]2		2	B,M	2	2	2	L,M
Bromus carinatus	1	1	1	B,M	2	2	2	L,M
Calamagrostis rubescens	4	4	3	M	3	3	2	M
Carex geyeri	2	2	2	M	2	2	2	M
Carex microptera and *hoodii*				B	2	2	2	L,M
Elymus glaucus	2	3	3	B,M	3	3	4	L,M
Phleum pratense						2	1	L
Poa pratensis	2			B	2	2	1	L
Forbs								
Achillea millefolium	1	2		B,M	2	2	1	L,M
Arnica cordifolia	3	3	2	B,M		2	1	L,M
Aster engelmannii	2	2	1	B,M	3	2	2	M
Aster foliaceous					2	2	1	L,M
Astragalus miser	2			B				
Balsamorhiza macrophylla	2	1	1	B	1	2	1	L
Castilleja miniata	2	2	2	M	2	2	1	M
Collomia linearis		1		B	1		2	L
Delphinium occidentale						2	2	M
Dracocephalum parviflorum		2		B,M		1		M
Epilobium angustifolium		1	1	B,M		2	1	M
Frageria vesca		2	2	M				L,M
Geranium viscosissimum	3	3	2	B,M	2	3	2	L,M
Iliamna rivularis	1	2	1	B,M		3	2	L,M
Lupinus spp.	2	2	2	B,M		2	2	L,M
Osmorhiza chilensis	2	2	2	B,M	2	2	1	L,M
Osmorhiza occidentale	1			B	2	3	1	L,M
Perideridia gairdneri					2	2	1	L,M
Polygonum douglasii					2	1	1	L,M
Pyrola secunda	2	1		M				
Rudbeckia occidentale					3	2	2	L
Sidalcea oregana						2	1	L
Solidago canadensis					2	2	1	L,M
Thalictrum fendleri	2	2	2	B,M	2	3	2	L,M
Wyethia amplexicaulis	2	1	2	B	1	1	1	L
Shrubs								
Amelanchier alnifolia	2	2	2	B,M	4	2	2	M
Berberis repens	2	2	2	B,M	3	2	2	M
Ceanothus velutinus	3	2	2	M	3	2	2	M
Pachistima myrsinites	3	1	2	B,M	3	1	1	M
Prunus virginiana	2	2		M	3	2	2	M
Rosa nutkana and *woodsii*	2	1	2	B,M	2	2	2	M
Shepherdia canadensis	3	2	2	B				
Symphoricarpos oreophilus	2	2	1	B,M	3	2	1	L,M

[1] B = Blue Jay; L = Little Bear; M = Manning Basin.

[2] Percentage cover of individual species was condensed from the original seven categories into the following classes:

1 = 5 percent or less, but more than a few plants
2 = 6 to 25 percent
3 = 26 to 50 percent
4 = 51 to 75 percent

No species occupied more than 75 percent cover. The untreated observations were recorded for control plots in all years and treatment plots in the preburn year. The year 2 and year 4 postburn observations were recorded for treatment plots.

Shrubs

Shrub response at Manning Basin was varied (table 8). In the mixed stand, biomass of shrubs increased slowly; it was only 31 percent of preburn biomass after 5 years. Biomass in the mixed stand control also increased during these same years, mainly myrtle pachistima. Other shrub species in the control decreased, suggesting that factors other than fire may have affected shrub response in the burned mixed stand. In the upper aspen stand, biomass was 66 percent of the preburn quantity after 5 years. Yearly fluctuations in stem density and biomass suggested that growth and mortality of new stems occurred in a dynamic, irregular process. In the lower aspen stand, which initially had high shrub cover, biomass exceeded the preburn level after the third growing season and remained about the same through the fifth season. After 5 years, shrub canopy was 60 to 80 percent of preburn coverage (table 8).

Based on the rate of recovery, both cover and biomass should reach preburn conditions within 5 to 10 years after fire, which is similar to recovery of shrub forage yields for other shrub communities (Wright 1972). All species were root crown shrubs except creeping barberry (*Berberis repens* Lindl.), which is rhizomatous; thus, all species were capable of sprouting, making rapid recovery of shrubs likely. At Little Bear and Blue Jay, biomass and cover of shrubs were initially low and remained that way. Increases in biomass were nonsignificant (table 8). Thus, the low-severity fire did not appear to influence shrub response.

The proportion of biomass containing foliage and stemwood less than 0.5 cm in diameter increased on all burned plots for 2 years following fire, then slowly decreased. It remained about 10 percent higher than on the control plots over the 5 postburn years. Thus, during this period a greater proportion of the shrub biomass was of a size desired by browsing animals.

Some individual species responded consistently and others varied among the stands at Manning Basin. Biomass of Saskatoon serviceberry (*Amelanchier alnifolia* Nutt.), known to resprout strongly after fire (Noste and Bushey 1987), recovered to preburn quantities within 3 years in the lower aspen stand and within 5 years in the mixed stand (table 9). After 5 years, it was only half of its preburn biomass in the upper aspen stand. Intense competition by wild hollyhock may have slowed its recovery. Where black chokecherry (*Prunus virginiana* var. *melanocarpa* [Nels.] Sarg.) was well established before fire in the lower aspen stand at Manning, its postburn biomass exceeded preburn biomass in two seasons and was twice preburn biomass after five seasons (table 9). In the other stands, where it was a minor component, it responded slowly.

In the aspen stand, biomass of snowbrush ceanothus increased substantially by sprouting. In the mixed stand, the density of sprouted stems was about half of preburn density, but biomass was considerably less than preburn levels. Some mortality to snowbrush ceanothus and the long time needed to regrow clumps of large diameter stems that existed before fire accounts for its slow recovery in the mixed stand. Also, some snowbrush ceanothus plants were killed by the fire, as has been observed in other burns (Noste 1985). A flush of snowbrush ceanothus seedlings appeared the first year after fire. Seedling density decreased markedly by the second year, but a much smaller decrease occurred after that (table 10). The increase in seedlings from the third to fourth growing

Table 8—Cover and accumulated shrub biomass before (P) and after fire accompanied by coefficients of variation and tests of significance

Location	Overstory-understory	Cover			Biomass year from fire						CV[2]	Year comparisons[1]		
		P	3	5	P	1	2	3	4	5		P:1	P:5	1:5
		- - - -*Percent* - - - -			- - - - - - - - - - - - - - *kg/ha* - - - - - - - - - - - - - -						*Percent*			
						Fire Treatments								
Little Bear	Aspen-tall forb	5	3	3	32	15	21	33	27	20	67	NS	NS	NS
Blue Jay	Mixed-forb	9	9	12	127	197	113	126	243	188	21	NS	NS	NS
Manning(U)	Aspen-shrub	34	15	28	881	303	237	309	479	535	19	0.05	0.05	NS
Manning(L)	Aspen-shrub	56	29	42	1,807	220	841	1,984	1,662	1,833	25	0.05	NS	0.05
Manning	Mixed-forb	23	12	14	[3]707	263	238	206	275	218	25	NS	0.10	NS
						Controls								
Little Bear	Aspen-tall forb	2	3	1	8	—	0	10	6	10	92	NS	NS	NS
Blue Jay	Mixed-forb	23	19	25	232	—	421	703	715	504	23	NS	NS	NS
Manning	Aspen-shrub	—	42	65	—	1,178	1,386	1,771	1,307	1,376	23	NS	NS	NS
Manning	Mixed-forb	—	33	27	—	646	792	923	733	909	38	NS	NS	NS

[1] An analysis of variance with years as treatments and Tukey's hsd test were performed to test for differences in biomass between selected years. Significance probabilities exceeded by the tests are given; NS is nonsignificant.

[2] CV = 100 (std. error/mean) for biomass averaged over all years.

[3] One outlier, a subplot that fell on an unusually large-stemmed slump of *Ceanothus velutinus* was eliminated. When included, the mean was 1,639 kg/ha.

Table 9—Biomass of individual shrub species 5 years after fire and its percentage of preburn biomass (in parentheses) for the fire treatments at Manning Basin

Species	Stand		
	Mixed	Aspen(U)	Aspen(L)
	kg/ha		
Amelanchier alnifolia	84 (100)	289 (46)	512 (101)
Berberis repens	47 (60)	93 (65)	47 (85)
Ceanothus velutinus	151 (14)	74 [1](4,720)	269 (216)
Pachistima myrsinites	53 (25)	12 (46)	81 (9)
Prunus virginiana	8 (4)	24 (60)	228 (138)
Rosa spp.	8 (94)	24 (307)	27 (58)
Salix scouleriana	0	0	668 [1](1,910)
Symphoricarpos oreophilus	<1 (21)	7 (40)	0

[1] The percentages are extremely high owing to small amounts of preburn biomass.

Table 10—Average number of snowbrush ceanothus (*Ceanothus velutinus*) seedlings per hectare and percentage frequency of occurrence on subplots at Manning Basin

Stand	Statistic	Year after fire			
		1	2	3	4
Mixed	Number	26,600	9,800	3,600	6,100
	Frequency	31	28	19	25
Aspen (U)	Number	25,500	13,100	9,000	12,300
	Frequency	47	50	50	44
Aspen (L)	Number	7,700	3,600	3,400	1,900
	Frequency	38	38	19	25

seasons suggests that germination of new seedlings occurred over several years. But the data are too limited to confirm this. Seedling biomass was included in the analysis although it was a minor component until 4 years after fire. Average seedling weight was 1.45 g in postburn year 3 and 4.80 g in year 4. By year 6, snowbrush ceanothus was beginning to dominate vegetal cover over major portions of the Manning burn.

Biomass of Scouler willow (*Salix scouleriana* Barratt) sprouts increased dramatically in the lower aspen stand, but no seedlings were observed. Biomass of myrtle pachistima increased slowly over the 5 postburn years in all stands. It was greatly reduced in the lower aspen stand. Coverage of myrtle pachistima was reduced substantially but should recover based on observed sprouting and seedlings.

Although creeping barberry is a small plant, it responded quickly after fire and increased its proportion of total shrub biomass in all stands. After 5 years, biomass was approximately two-thirds of preburn quantities. Biomass of Nootka rose (*Rosa nutkana* Presl.) or Woods rose (*R. woodsii* Lindl.) recovered to near preburn quantities by the second postburn year and fluctuated after that.

Aspen Suckers

Sucker response varied among the stands probably owing to differences in fire severity, vigor of clone, and postburn plant competition (fig. 4). Postburn sucker densities peaked in either the first or second postburn year and declined from peak levels by factors of 0.2 to 0.5 to their fifth year densities. Peak postburn densities ranged from nearly 0.5 to 5.0 times preburn densities.

Sucker densities remained low, up to a maximum of 3,000 per hectare, following low-severity fire. At Little Bear, densities declined from preburn levels on both control and treated plots. This stand appeared to be deteriorating even before fire. At Blue Jay, densities increased from none before fire to a small number after fire. But the remaining substantial overstory of aspen and conifers discouraged sucker development.

Following moderate- to high-severity fire at Manning, peak sucker densities ranged from 17,000 to 39,000 per hectare and were within the range of densities reported for other fires in western aspen (Bartos 1981; Brown and DeByle 1987; Patton and Avant 1970). The different patterns of response are worth noting. In the mixed stand, sucker numbers decreased significantly from preburn densities, but biomass of suckers increased steadily from postburn year 1 (fig. 4). Thus, even though fewer suckers existed after fire, aspen may have benefited because conifer cover was reduced and suckers were growing into the spaces previously occupied by conifers.

In the upper aspen stand, suckers increased by fivefold the second year then declined to 2,860 per hectare in postburn year 5, which was less than the preburn density. Although suckers declined markedly to a rather low density, sucker biomass was almost twice that of preburn biomass, indicating that aspen trees would establish an overstory. In the lower aspen stand, many suckers existed before fire because the stand had been opened up by earlier heavy snow breakage that encouraged suckering. Even so, postburn sucker densities were nearly double that of preburn numbers in year 1, then declined to less than preburn numbers in year 5. But biomass was 914 kg/ha by year 5, which slightly exceeded preburn amounts. In this case, only 6 percent of the suckers exceeded 2 m in height, yet accounted for 37 percent of the biomass. In all of the Manning stands, the proportion of suckers exceeding 0.5 m in height was greater in year 5 than before fire (fig. 4).

Although production of herbaceous vegetation increased in all treated stands, the pattern of early vegetal succession varied. Accumulated understory biomass of herbs, shrubs, and suckers peaked in year 1 where fire severity was low (fig. 5A, B) and in year 2, 3, and 4 where fire severity was moderate to high. Peaking of accumulated biomass primarily reflected fluctuations in production of herbaceous vegetation. The aspen stands in the Manning burn showed two early successional patterns, domination in one by herbs (fig. 5C) and the other by woody plants (fig. 5D). In the stand dominated by woody plants, 67 percent of the woody biomass was shrubs and 33 percent was aspen suckers. These percentages held for preburn vegetation and in postburn years 3 and 4. Thus, the aspen-shrub stands returned rapidly to the preburn proportions of shrubs and suckers. The early successional pattern in the mixed stand (fig. 5E), dominated by a woody understory before fire, indicated a slower postburn recovery to domination by woody plants.

In a study of vegetation recovery following a large wildfire in mixed conifers, seral patterns also varied considerably, ranging from long-lasting herb stage to rapid regrowth of shrubs that dominated herbs (Stickney 1986). Varied patterns of seral vegetation following fire occur commonly within individual burns.

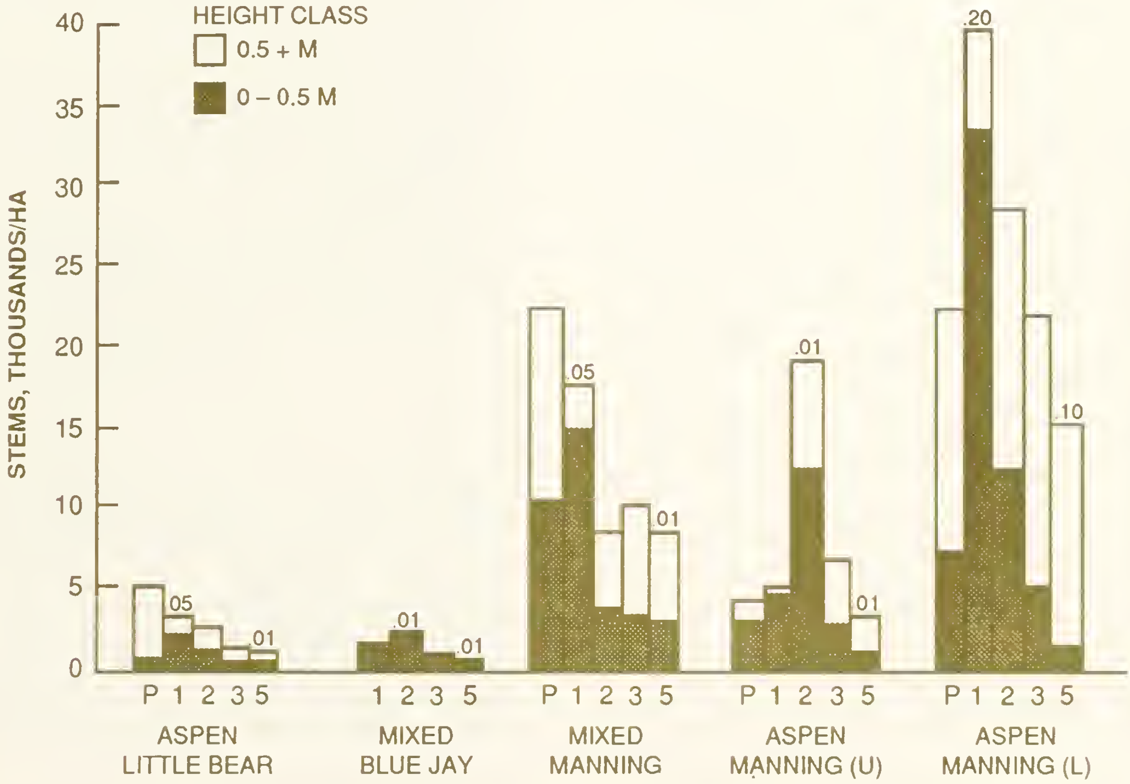

Figure 4—Density of aspen suckers by height class for preburn (P) and postburn years 1, 2, 3, and 5. Few suckers exceeded 2 m in height, so they were included in the 0.5+-m class. No preburn suckers were observed at Blue Jay. Sucker counts were not normally distributed. A logarithmic transformation of the differences in total sucker density between years was normally distributed. A paired comparison t-test on these differences between preburn and postburn peak density and between preburn and postburn year 5 density was performed. The values above the bars are the significant difference confidence levels.

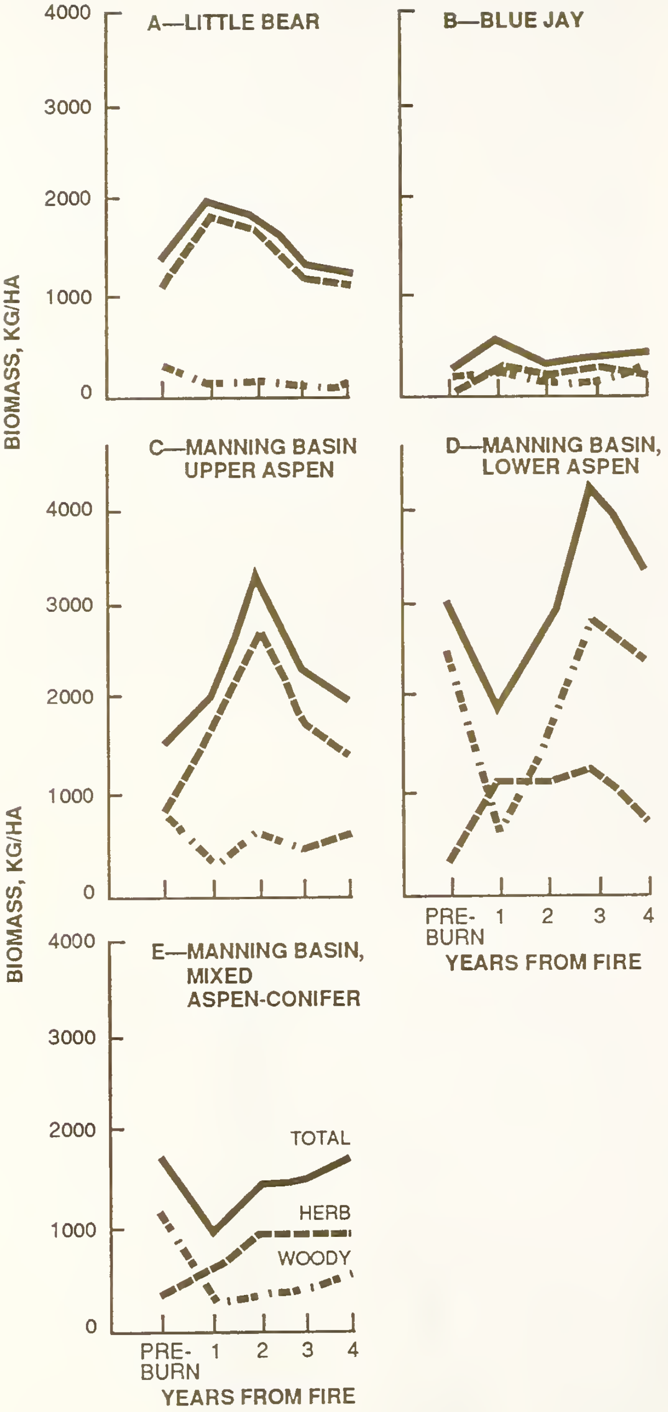

Figure 5—Accumulated biomass of herbaceous vegetation (unadjusted) and woody plants (shrubs and aspen suckers) before and after fire in five stand categories.

Almost all species present before fire were adapted to survival as endurers (Rowe 1983) capable of resprouting from belowground organs. Our findings agreed with the conceptual model of Lyon and Stickney (1976) that a majority of species on site before fire will reestablish and that dominating species will establish in 1 year. But the model suggests little about the structure of vegetation that can vary greatly. In one of four stands, for example, no extant plants of wild hollyhock were present on the site before fire, but it dominated the postburn vegetation for 3 years.

DISCUSSION AND CONCLUSIONS

Fire severity appeared to influence the composition of herbaceous vegetation. The proportion of forbs increased on plots receiving high severity treatment and decreased on plots receiving low severity fire. However, separating the influences of fire severity and preburn plant composition on postburn composition was not possible. Fire severity appeared to have little effect on herbaceous biomass in that all burns responded with increased production relative to controls.

Low-severity fire had little measurable effect on cover and biomass of shrubs. Moderate- to high-severity fire at Manning induced varied regrowth of shrubs. For example, sprouting of snowbrush ceanothus was considerably less in the mixed stand, where some large plants were killed. Mortality may have been caused by consumption of an excessive buildup of leaf litter that caused prolonged downward heating around the root crowns. Species that sprout from root crowns are more vulnerable than those that sprout from farther below the soil surface. Effects of heat on individual plants can vary considerably within moderate and high severity fires because of localized burning conditions.

Abundant aspen suckers were produced in the moderate- to high-severity fire. Sucker response to low-severity fire was poor, perhaps for several reasons: (1) too few aspen were killed by fire, (2) competition from an overstory of aspen and conifers remained, and (3) one stand appeared to be in poor health. Killing a high proportion of aspen trees should favor suckering because apical dominance is reduced and sucker-stimulating cytokinins are increased in the roots (Schier 1981). A strong relationship between suckering and fire severity was not demonstrated here nor previously (Brown and DeByle 1987), probably because other factors that are difficult to separate from fire severity such as parent stand vigor, density of aspen root systems, soil characteristics, clonal characteristics, and competition with other vegetation also influence sucker response. Early postfire sucker response can vary greatly, but large numbers of suckers are probably not necessary to establish new stands of aspen where management is primarily for range and wildlife resources. Following fire, high sucker densities decline considerably over the first 5 years, while initial low densities decline little (Bartos 1981; Brown and DeByle 1987). In mixed stands the most important factor affecting redevelopment of aspen following fire is probably reduced conifer competition.

Determination of the effects of fire severity on postfire vegetation response was hampered in this study, as it is in field studies generally, because the fire treatment is only one factor influencing postfire responses. Other factors influencing prediction of postburn vegetation response are (1) prefire vegetation, (2) species adaptations to fire, (3) environmental conditions, and (4) chance (Lyon and Stickney 1976; Morgan and Neuenschwander 1985; Rowe 1983). The complexity of vegetation response is illustrated by the aspen stands at Manning that had high fire severity. One species, wild hollyhock, which germinated from seed stored in the soil, dominated the upper stand but was absent from the lower stand. The preburn plant community appears to be the most important factor. It can have a greater effect on understory vegetation response than intensity (Armour and others 1984) and severity of surface fires. Because many factors influence recovery of postfire vegetation, some owing to chance, variable vegetation responses should be expected to fires of the same severity and intensity.

For applying prescribed fire, this study supports the need to choose good opportunities for achieving sustained spread of fire. Dead woody fuels less than 2 cm diameter are needed to help ignite larger woody fuels and to provide adequate flame residence time to kill aspen. Shrubs contribute significantly to good burning opportunities (Brown and Simmerman 1986). Prescribed fires of moderate to high severity are needed to assure sustained spread and sufficient mortality to the overstory (Brown and DeByle 1987). If the conifer component cannot be reduced with prescribed fire, managers should augment the fire with cutting. Land managers should expect varied response in suckers, shrubs, and herbaceous vegetation during early postfire years.

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Biomass of grasses, forbs, shrubs, and aspen suckers was determined annually for three prescribed fires in aspen and aspen-conifer forests in southeastern Idaho and western Wyoming. Fires ranged from low to high severity and overstory mortality from 20 to 100 percent. Over 4 postburn years, production of grasses and forbs averaged 1.5 to 3.3 times that of controls. After 5 years, shrub biomass was 21 to 100 percent of preburn biomass. The varied patterns of seral vegetation and their management implications are discussed.

KEYWORDS: fire severity, understory vegetation

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